Protecting Patients through Dynamic Network Analysis of Hospital Department Relationships

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November 15, 2012

(Joint work with Bradley Malin and Steve Nyemba)
$675,000 for Privacy Violation

Jail Time for Malicious Accesses

California Hospitals Fined $675,000 For Privacy Violations: Jun 11, 2010

What Every Risk Manager Needs To Know About Copy Machines: May 8, 2010 CBS exposes the risks to healthcare and other entities for possible data breach violations, financial privacy law violations, HIPAA violations, and makes them vulnerable to being targeted by criminals for theft or other crimes. The video also shows an example of how they can be exploited by terrorists. Of course, that is in addition to the risks posed by improper use and distribution of copies themselves. View Here.

Be Prepared To Deal With Exploding Medical ID Theft And Privacy Issues In Healthcare: May 3, 2010 Medical ID Theft is hitting the headlines as organized crime and ID thieves grab millions in false claims and leave innocent patients and healthcare providers with the bills. By Stephen A. Frew JD.

Hospital Employee Gets Jail Time For HIPAA Violation: Apr 29, 2010 Hospital employee sentenced to federal prison for 3-week long medical records spree.

UCLA Employee Indicted For Celebrity Privacy Violations: May 8, 2008 Hospital employee sells celebrity medical info to tabloids.
Patient information needs to be protected from insiders

• Traditional security practices (e.g., role-based access control) are insufficient to ensure EMR security
  – Common for >100 employees to access a patient’s medical record during their visit
  – Often difficult to determine who the members of a care team are and who will need access to what information at which time
EHRs have adopted collaborative capabilities to facilitate interaction between teammates and coordinate care

• We hypothesize that HCO departments will exhibit predictable interaction behavior

• Our goals:
  1. Investigate if such behavior exists
  2. If so, determine if it is stable
     • If stable interactions become unstable → associated patients will be anomalous
The dependent relations between green departments and red departments are very low

Our goal is to retrieve the dependent relations of departments and determine whether the dependencies among departments touching that patient are expected?
Two general objects of EHR access logs

Departments, job titles, roles...

Diagnosis codes, location...

U(sers)

P(atients)

Access

\[ u_1, u_2, u_3, u_4, u_5, u_6 \]

\[ p_1, p_2, p_3, p_4, p_5, p_6, p_7 \]
Auditing Models on EHRs systems

**Supervised**
- Logic regression and SVM

**Unsupervised**
- CADS, MetaCADS
- SNAD
- Access Explanation

**Relational Analysis**
- Users Communication
- Departments Communication

Our works will investigate whether the relations of departments are stable or not and how the dynamic characteristics could be applied to assess if the set of specific accesses associated with a particular patient record were anomalous.

Healthcare Interaction Networks

Tripartite graph of departments, users and patients

Bipartite graph of departments and patients

Health interaction network

Local view for p₆

Global view
Where are We Going?

**A Global Network of Departments**

Two metrics: certainty and reciprocity

Stable status in terms of the two metrics

**Local Network-for a specific patient**

Two metrics: local network score and reciprocity

**Application of the Networks**

Detecting patients with anomalous medical records accesses
Certainty to Model Relationship of Global Network

Cert(Lifeflight event medicine (d₃)->Emergency medicine (d₁)) = 4/4

Cert(Inpatient medicine(d₂)->Inpatient medicine(d₂)) = 6/7
Using reciprocity to characterize the mutual interaction between all pairs of departments in the global network

Reciprocity = 1

Pediatric Emergency Dept -> Peds Respiratory Care = 0.57

Peds Respiratory Care -> Pediatric Emergency Dept = 0.037
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Dataset used for this study

- Vanderbilt University Medical Center “StarPanel”
- 3 months in 2010
- Arbitrary Week
  - ≈ 9,200 users
  - ≈ 99,000 patient records
  - ≈ 400,000 accesses
  - ≈ 450 departments
Although the relations of the network are very unbalanced, the unbalance is stable over time.

<table>
<thead>
<tr>
<th>Time</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reciprocity</td>
<td>0.267</td>
<td>0.2814</td>
<td>0.2858</td>
<td>0.2871</td>
</tr>
</tbody>
</table>

\[
\frac{(0.2814 - 0.267)}{0.267} = 0.05
\]

Week 1 to week 2
The changes become smaller over time (centralization: green > blue > red)

Degree of relations between departments changes little over time

>82.5% of the change resides in [-0.25, 0.25]
Strong relations between VUMC departments over a four week period

<table>
<thead>
<tr>
<th>Department ( (d_i) )</th>
<th>Department ( (d_j) )</th>
<th>Min Certainty</th>
<th>Max Certainty</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intradepartmental Relations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4East OB/GYN</td>
<td>4East OB/GYN</td>
<td>0.74319</td>
<td>0.7669</td>
</tr>
<tr>
<td>Adult Emergency Medicine</td>
<td>Adult Emergency Medicine</td>
<td>0.74024</td>
<td>0.78453</td>
</tr>
<tr>
<td>Cancer Infusion Center</td>
<td>Cancer Infusion Center</td>
<td>0.73171</td>
<td>0.844</td>
</tr>
<tr>
<td>8N Inpatient Medicine</td>
<td>8N Inpatient Medicine</td>
<td>0.7197</td>
<td>0.80909</td>
</tr>
<tr>
<td>Newborn Nursery</td>
<td>Newborn Nursery</td>
<td>0.70406</td>
<td>0.72727</td>
</tr>
<tr>
<td><strong>Interdepartmental Relations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOT Radiology</td>
<td>Orthopaedics</td>
<td>0.99621</td>
<td>1</td>
</tr>
<tr>
<td>Nursing Education and Development</td>
<td>Medical Information Services</td>
<td>0.95833</td>
<td>1</td>
</tr>
<tr>
<td>Main OR - Trauma/Renal</td>
<td>Medical Information Services</td>
<td>0.94444</td>
<td>1</td>
</tr>
<tr>
<td>Life Flight Event Medicine</td>
<td>Emergency Medicine</td>
<td>0.90805</td>
<td>1</td>
</tr>
<tr>
<td>Emergency Medicine Admin</td>
<td>Adult Emergency Medicine</td>
<td>0.91489</td>
<td>0.94186</td>
</tr>
</tbody>
</table>
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Local view for $p_6$
Evolution of Local Networks in Terms of Local Network Score and Local Network Reciprocity

Each point in $P_{\text{start}}$ corresponds to a local network.
Over 98% of patients are normal because they exhibit a score change $<0.05$
Approximately 99% of patients are normal because they have a change of reciprocity <0.1
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p2 has -0.93 change of local network score and -0.79 change of local reciprocity from the 1st to the 2nd week.
Conclusions

• We hypothesized an HCO would exhibit strong stability confirmed by our experiments

• We can characterize how strange a patient’s local network appears
  – Two groups of patients; those with small changes in local network score and reciprocity score and those with significant changes
  – The changes in the latter group do not justify the claim that the patient has been intruded upon, but may provide a reason for an investigation that incorporates more nuanced domain knowledge
• Global and local networks appear to represent the business processes of HCO departments
  – however, such claims must be confirmed with employees knowledge about the working of the medical center and its affiliated clinics

• Need to specialize tool to account for semantics of patients
  – Patient: \{Diagnosis, Procedure, Demographics, Residence, physical location in a hospital\}

  – Incorporating semantics about the patient, \(p_2\) in the last figure may have no intrusion; rather it is likely a complex cancer patient, which could be confirmed by inspection of clinical documents in the medical record
Acknowledgements

**Vanderbilt**
- Dario Giuse, Dr. Ing
- **Bradley Malin, Ph.D.**
- Steve Nyemba, M.S.
- John Paulett, M.S.
- Wen Zhang, M.S.

**UIUC**
- Carl Gunter, Ph.D

**Northwestern**
- David Liebovitz, M.D.
- Sanjay Mehotra, Ph.D.

**Funding**
- National Science Foundation
  - CCF-0424422 (TRUST)
  - CNS-0964063
- National Institutes of Health
  - R01LM010207
Questions? Comments?

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Health Information Privacy Lab:
http://www.hiplab.org/